ATMOSPHERIC ELECTRICITY IN HIGH LATITUDES.

[We print some extracts from a memoir by Mr. George C. Simpson, to whom we are also indebted for a special article in the present number of the REVIEW. Those who wish to acquire a clear idea of modern methods of work in the study of atmospheric electricity will necessarily obtain and read the whole of Mr. Simpson's memoir, which is published in volume 205, series A, of the Philosophical Transactions of the Royal Society of London.—EDITOR.]

Investigation into the problems of atmospheric electricity may be divided into two periods. The first period was devoted almost entirely to measurements of the normal potential gradient in the lower region of the earth's atmosphere, with the aim of finding its daily and yearly variations, its geographical distribution, and its dependence on meteorological conditions. To this period belongs the fine work of Lord Kelvin and Professor Exner.[1]

The second period commenced in 1899, when the interest in the problems of atmospheric electricity was at rather a low ebb, owing to the small real progress made during the few previous years. In that year the discovery that atmospheric air is always more or less ionized (made at about the same time by Elster and Geitel[2] in Germany and C. T. R. Wilson[3] in England) had a completely revolutionizing influence on the theories held to account for the earth's normal field. This discovery has brought about a great revival of interest and opened a totally new field for investigation.

As long as air could be considered a perfect nonconductor, Exner's theory that the charge on the earth is a residual charge held a very strong position, but with a conducting atmosphere it is untenable. An ionized atmosphere means a continual passage of electricity from the charged surface into the highest regions of the atmosphere, where only any residual charge could be held. The new discovery having proved conclusively that the charge on the earth is being continuously dissipated into the ionized air above, it became of prime importance to determine the rate at which the electricity is dissipated and the conditions under which the loss takes place.

The first serious attempt to do this was made by Elster and Geitel.[4] They designed an instrument consisting of a charged cylinder exposed to the air—protected from extraneous electrical fields—and so connected to an electroscope that the rate at which it lost its charge could be measured. By making certain assumptions it can be shown that the charge lost in a small interval of time from any charged body exposed to the air is always a definite fraction of the charge on the body. Thus, when Elster and Geitel had found the charge lost by their cylinder in a minute they were able to express the loss as a percentage of the charge on the cylinder, and then, by applying this percentage to the charge on the earth, were able to find the quantity of electricity being dissipated from every square meter of surface each minute.

Besides knowing the amount of electricity dissipated from the surface—which depends upon many factors—it became also of great importance to know to what extent the air is ionized at any moment. For this purpose Ebert[5] designed an instrument which gives the amount of ionization independently of anything else. A known quantity of air is drawn through a cylinder condenser, the inner cylinder of which is connected to an electroscope. As the air passes between the cylinders the charged inner one attracts to it all the ions of the opposite sign. These ions neutralize an equal amount of electricity, and so the charge lost by the inner cylinder is a measure of the number of ions contained in the known quantity of air which has been drawn through the instrument. In this way it is possible to find how many electrostatic units of each kind of electricity are free in a cubic meter of air.

These two instruments are very powerful weapons for attacking the new problems of atmospheric electricity, and have been used as such to a large extent on the Continent. Systematic observations of the dissipation were undertaken by Elster and Geitel, and quite a number of other physicists have devoted themselves to finding the relations existing between meteorological conditions, ionization, the rate of dissipation, and the potential gradient. As a result of this work the electrical conditions of the atmosphere are already fairly well known for lands lying within the temperate zone. With the idea of extending this knowledge to places within the Arctic Circle I was granted permission by the Commissioners of the 1851 Exhibition Scholarship to undertake a year's work [September 1903–October 1904] on atmospheric electricity in Lapland.

The work which I proposed to do was the following:

1. By means of a Benndorf self-registering electrometer to obtain daily curves of the potential gradient and from these to calculate the yearly and daily variations.
2. To make systematic observations of the dissipation by means of Elster and Geitel's instrument.
3. To make corresponding measurements of the ionization with Ebert's apparatus.
4. To measure the amount of radio-active emanation in the atmosphere.
5. To investigate, as far as possible, the influence of the aurora on the electrical conditions of the atmosphere.

In my choice of a station I decided to get as far north as possible without being actually on the seacoast, and found that the Lapp village of Karasjok (69° 17′ north, 25° 35′ east, 129 meters above sea level) was very well suited for my purpose.

METEOROLOGICAL CONDITIONS.

Before going on to a discussion of the electrical results obtained, it will be as well to give a short account of the meteorological conditions experienced during the year's work. From its high latitude the north of Norway should be a very cold district; but the presence of the open ocean on the north and west greatly modifies the temperature. The effect of the water is of course very much more marked on the seacoast than inland. As one recedes from the coast the mean temperature for the winter six months falls very rapidly, it being −2.3° C. at Gjesvoer, near the North Cape, and −11.7° C. at Karasjok. If there were no interchange of air between the ocean and the interior of the land the latter would of course have a very low temperature. This became very noticeable during periods of calm weather, for the temperature would then run down to very low values, reaching on several occasions −40° C., while, on the contrary, whenever the wind rose the temperature rose also.

When there was no wind, a cap of very cold air would form over the land, causing a nearly permanent temperature inversion. Although I could not observe this inversion instrumentally—neither kites nor balloons forming part of my equipment—there could be little doubt as to its reality. On September 30, 1903, with an air temperature of −6° C., a bright rainbow was observed. Then again, on descending the high banks of the river, one felt at once the cold air collected in the river basin, and the Lapps stated that it was seldom as cold on the hills as in the valleys. Then, again, the fact that a wind was always accompanied by mild weather also points to the cold of still weather being confined to a layer of air of no considerable depth lying over the surface. This condition of things almost entirely prevented the formation of ascending currents of air, thus causing very small values of the amount of precipitation and almost entirely preventing the

[1] For a good résumé of this period see Exner, Terr. Mag., 1900, vol. 5, p. 167.
[2] Phys. Zeit., 1899, vol. 1, p. 245. Phys. Zeit., 1900, vol. 2, p. 116.
[3] Roy. Soc. Proc., 1901, vol. 68, p. 151.
[4] Phys. Zeit., 1899, vol. 1, p. 11. Terr. Mag. and Atm. Elect., 1899, vol. 4, p. 213. Drude's Ann., 1900, vol. 2, p. 425.
[5] Short description, Phys. Zeit., 1901, vol. 2, p. 662; fuller description, Aeronautische Mittheilungen, 1902, p. 1.

formation of low clouds during the winter. It also had a very marked effect on the electrical condition of the atmosphere, to which reference will be made later.

During the summer the weather conditions were very similar to those of England, with the exception that the precipitation was very much less and thunderstorms were scarce. On three days only was thunder heard and lightning was not seen once.

From November 26, 1903, to January 18, 1904, the sun did not rise above the horizon; nevertheless, even in the darkest days there were two or three hours of twilight, during which the sky was too bright for the stars to be seen. The period during which the sun did not go below the horizon extended from May 20 to July 22, 1904.

[Perhaps we may summarize the conclusions that Mr. Simpson has drawn from his year's work in Lapland by quoting the following sentences.]

During the whole of my stay in Karasjok I could not detect the slightest effect of the aurora on any of the electrical conditions of the atmosphere, and most careful watching of the needle of the self-registering electrometer did not show any relation between the potential gradient and the aurora. * * *

The first and most important conclusion is that the difference in the electrical conditions of the atmosphere between mid-Europe and this northerly station can all be accounted for by the difference in the meteorological conditions at the two places. * * * The maximum of the transparency of the atmosphere corresponded with the maximum of the ionization.

The potential gradient runs exactly opposite to the dissipation, as though there were a constant charge of negative electricity being given to the surface of the earth during the whole year, while the amount at any moment on the surface, measured of course by the potential gradient, is determined by the rate at which the charge is being dissipated. How this charge is supplied to the earth still remains, in spite of many theories, one of the unsolved problems of atmospheric electricity. * * * My observations do not show that great increase in dissipation that has been ascribed to high latitudes by some writers. * * *

[With regard to atmospheric radio-activity Mr. Simpson says:]

In 1901 Elster and Geitel[6] made the very important discovery that the atmosphere always contains more or less radioactive emanation. Since this discovery several workers have repeated the observations and confirmed the results. During the whole of 1902 Elster and Geitel[7] made daily observations of the radio-activity, and found that the amount of emanation in the atmosphere depends largely on some meteorological conditions, such as the rising or falling of the barometer and temperature; and, as a result of their work, they made the suggestion that the emanation in the air is supplied entirely by the radium or radio-active emanation contained in the soil.

The method used by Elster and Geitel to detect and measure the emanation in the air, which has been adopted by other observers, consisted of stretching a wire about ten meters long between insulators in the open air. This wire was then charged to a negative potential of between 2000 and 2500 volts. After the wire had been exposed to the air at this potential for two hours, it was removed and wrapped round a net cylinder fitting inside the "protection cylinder" attached to their dissipation apparatus (specially closed at the bottom as well as the top for this measurement), and the rate at which the electroscope discharged was determined. When one meter of the wire discharged the electroscope one volt in one hour, the atmospheric activity was said to be unity and written $A=1$.

Using Elster and Geitel's method, I made observations of the atmospheric radio-activity in Karasjok.

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As each observation occupied over two hours I made three observations daily for a month; * * * for one week out of the four I continued observations during the night; this was done for each alternate month, and gave a good idea of the annual and diurnal courses of the radio-activity. * * *

The radio-activity is constant and very high from September to February, inclusive. A maximum falls in midwinter and a minimum in midsummer. A diurnal maximum occurs in the early hours of the morning, and a minimum about midday. * * * Temperature plays a secondary part in determining the amount of activity in the air. Relative humidity appears to have a very large effect [the activity increasing with relative humidity]. The wind strength has a most direct influence [the greatest activity occurring with feeblest wind]. The radio-activity is greater with a falling than with a rising barometer. It is also greater with a low than with a high barometer in some months, especially April, May, and June, but no relation appears for the year considered as a whole. The influence of cloudiness is not clearly shown. The direction of the wind appears to give a maximum with a south wind, and a minimum with a north wind, but this may be only a restatement of the relation between activity and a rising or falling barometer. No relation between radio-activity and potential gradient can be detected, either in the separate months or in the whole year. * * *

This analysis gives an exceedingly strong support to Elster and Geitel's theory of the origin of the atmospheric radioactive emanation. According to their theory, the air which is mixed up with the soil of the ground becomes highly charged with radium emanation.[8] When the barometer falls, this air passes out of the ground into the atmosphere, bringing with it its charge of emanation.

All the facts of the above analysis receive a very simple explanation by this theory if one extends it to include the fact that, as the emanation is a gas contained in the soil, it must constantly diffuse into the atmosphere above quite independently of the state of the barometer. Assuming this constant diffusion we at once see that whatever tends to reduce the atmospheric circulation, namely, to keep the air stagnant, tends also to increase the quantity of emanation in the lower layers of the atmosphere. * * *

One strange fact is that the radio-activity should be so high during the winter when the whole country is covered with snow * * * but the reason is not hard to find if it be remembered that the snow must form a very large reservoir to hold the emanation as it is escaping from the soil. It would be interesting to see if air drawn from the snow in the way Elster and Geitel drew it from the ground is charged with emanation. * * *

Elster and Geitel concluded that the radio-activity increased from the sea inland. In order to find if the same conditions hold true in the north I stayed in Hammerfest on my way home and made daily observations for four weeks. The result was in entire agreement with Elster and Geitel, and these observations also showed the great variation of radio-activity with the direction of the wind. * * *

During my year in Karasjok there were not many exceptionally fine auroras, and colored auroras were very rare. From the one or two I did see the colors appeared to be of two distinct kinds (by colors in this connection I mean colors other than the greenish-white light of the ordinary aurora.) There is first the mass of colored light which retains its form and

[6] Phys. Zeit., 1901, vol. 2, p. 590. [7] Phys. Zeit., 1903, vol. 4, p. 526.

[8] Phys. Zeit., 1904, vol. 5, p. 11; Terr. Mag., 1904, vol. 9, p. 49.

color for a comparatively long time, and beside this the colors which flash out and disappear immediately. A very interesting fact struck me with regard to the latter class. It is generally known that an auroral arch is often composed of a series of spear-like shafts of light arranged perpendicularly to the direction of the arch, which appear to be in constant motion. A number of these spears will suddenly become brilliant and the lower ends shoot out of the arch into the black sky below. The brilliancy will then run along the arch like a wave of light, lighting up all the spears as it goes along. I noticed that the "front" of such a wave of brilliancy and the points of the spears *when shooting out* were bright red, but as soon as the motion stopped the color disappeared, while the more violent the motion the purer and brighter the red. It appeared as if some physical process accompanied the passage of the auroral beam through the air and gave out a red light. For example, if the air had to be ionized before the discharge could pass through, then the process of ionization produced red light. If the motion was particularly violent, the production of red light would be followed by a production of brilliant green light, so that if a bright wave passed along an arch two waves of color would appear to travel along, first a wave of red light, closely followed by a green wave, the two traveling so closely together as to appear as one wave having a two-colored crest. Similarly spears shooting out with a great velocity would appear to have red and green tips.

The question of the relation of clouds to auroras has been very often raised. Three of my observations bear on this point.

On the evening of October 11, 1903, after a fairly active display, the aurora disappeared; but its place was taken by a system of narrow bands of cirrus clouds stretching right across the sky, which, being illuminated by the bright moon, had all the appearance of the aurora. That they did not form part of the aurora could only be decided at first owing to no line appearing in the spectroscope when pointed at them; but later there could be no doubt, as they partly obscured the moon.

On October 26 a very similar phenomenon again appeared; that which at first was taken to be aurora, later turned out to be cloud.

On December 13 the most brilliant auroral display of my stay took place. The whole display reached a climax at 9:45, when a most brilliantly colored corona shot out from the zenith. While this final brilliant display was taking place the sky suddenly became thinly overcast, and the aurora was only visible later as bright patches through the clouds.

It has long been a matter of controversy as to whether the aurora ever extends into the lower legions of the atmosphere. Several observers positively affirm that they have seen it quite close to the ground. This may be due to an optical illusion. One evening I was, for a considerable time, in doubt as to whether the aurora was really under the clouds or not. All over the sky were detached clouds, the clouds being of about the same size and shape as the spaces between them. Right across the sky a long narrow auroral beam stretched, showing bright and dark patches owing to the clouds. It looked exactly as if the auroral beam ran along under the clouds brightly illuminating the patches of cloud which it met. In reality the bright patches were the openings and not the clouds. It took me a long time to make quite certain of this, and it was only by at last seeing a star in the middle of a bright patch that I could be quite certain.

Lemström strongly supported the idea that the aurora often penetrates down to the earth's surface, and described how on one occasion the auroral line appeared in a spectroscope pointed at a black cloth only one or two meters away. I was able to repeat this observation on several occasions, and found that the line which then appeared in the spectroscope was not due to an auroral discharge in the air between the spectroscope and the black cloth, but was due to reflected light, which it was impossible to prevent entering the spectroscope, as the whole landscape was lit up with the monochromatic light of the aurora.

All the time I observed the aurora I could not detect the slightest noise accompanying the discharge.

THE TIME OF MOONRISE AND MOONSET.[1]

By WM. F. RIGGE, S. J., Creighton University, Omaha, Nebr.

On account of the moon's rapid motion both in right ascension and in declination, the computation of the times of the moon's rising and setting is apt to prove very laborious, since it can not be done except by successive approximations. The object of this article is to explain a very rapid method to be used for this purpose. While it may be an old one, the writer's reason for presenting it is that he has never found it in print.

The method to be described is a graphic one and requires in advance the construction of three diagrams, which we may denote A, B, and C. In order to show their practical use, they have been prepared for Omaha, Nebr. The problem before us, therefore, is to find the central [standard] times of moonrise and moonset at Omaha.

1. The first thing to be done is to find the time of the moon's meridian passage. This is given for Greenwich on page IV of every month in the American Ephemeris.[2] To reduce it to Omaha and to central time, we must add to it 6.4 (the Greenwich longitude of Omaha being $+ 6^h 23.8^m$) times the hourly difference there given, plus 23.8 minutes. This is done rapidly by means of diagram A, whose construction needs no explanation. Thus for January 13, 1906, when the time of the moon's transit over the meridian of Greenwich is $14^h 58.4^m$ and the hourly difference is 2.13^m, we find that 2.13 on diagram A indicates something over 37 minutes, which added to the Greenwich time gives $15^h 36^m$ as the central time of the moon's transit at Omaha.

2. The next step is to find the moon's hour angle. This is shown on diagram B for Omaha, the latitude being $+ 41° 16'$. The formula

$$\cos \tau = - \tan \varphi \tan \delta$$

gives the true hour angle, which must be corrected for refraction and parallax. For purpose of prediction it is evident that only the mean refraction or 36′ can be taken. Special computation will show that this diminishes the hour angle by 3.1^m for all values of δ between plus and minus 30°. For the parallax the mean value of 57.6′

[1] Many of the Weather Bureau observers, when called into court to testify as to the state of the weather at a given time, are asked whether the moon had risen, and they have, therefore, requested the Central Office to furnish them with tables of moonrise and moonset. As such tables, in order to be at all accurate, must be computed for each locality, it is proper that the work should be done by the astronomers of the Nautical Almanac. But this is not always practicable and the tables given in the ordinary popular almanacs are not sufficiently accurate or extensive. A graphic method has just been published by Rev. W. F. Rigge, of Creighton University, Omaha, Nebr., (see Popular Astronomy, Vol. XIII, No. 10). This will enable any one to compute the times of rising and setting for a whole month or year in a short time, utilizing the data given in the Nautical Almanac. We, therefore, reprint the following article by Professor Rigge, in the conviction that many of our readers will make use of his method.—EDITOR.

[2] Page IV of the American Ephemeris and Nautical Almanac gives the following items in Greenwich mean time:

(1) The semidiameter of the moon at Greenwich mean noon and (2) at midnight.

(3) The horizontal parallax of the moon for Greenwich mean noon and (4) mean midnight, with (5) and (6) the rate of change of each in one hour.

(7) The Greenwich mean time of the upper transit of the moon's center across the meridian of Greenwich, and (8) the rate of change of this time for an hour, whence the time of transit over any other meridian can be computed.

(9) Finally the age of the moon at Greenwich mean noon, counting from the moment of conjunction with the sun.

The following are the figures for January 13, 1906:

(1) 15′ 44.9″, (2) 15′ 48.4″, (3) 57′ 42.0″, (4) 57′ 54.9″, (5) +1.11″, (6) +1.05″, (7) $14^h 58.4^m$, (8) 2.13^m, (9) 18.3 days.